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COMPRESSIVE STRENGTH RELATIONSHIPS AND FACTORS

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ABSTRACT

Relationships between compressive strength tests and the elastic properties of containerboard and combined board are discussed. It is shown that the elastic stiffnesses of containerboard correlate well with short span compressive strength tests. They also correlate well with combined board edgewise compression. In other work results show that ring crush and short span compressive strength tests are generally well related; however, such relationships will not hold under all papermaking conditions. In one example where wet pressing was varied, the short span compressive strength results on medium properly predicted increases in combined board compressive strength; however, the ring crush results exhibited a maximum at intermediate densities and hence, failed to properly predict the observed increases in combined board ECT. New developments in combined board edgewise compression testing include special cutters for specimen preparation and test fixtures. They offer promise of reducing test time and test variability.

INTRODUCTION

During their service life corrugated containers are often subjected to high compressive loads. Therefore, compressive strength is an important end-use requirement for corrugated boxes. McKee, et al. (1963) showed that the top load compressive strength of a box is primarily dependent on two properties of the combined board. They are edgewise compressive strength (ECT) and flexural stiffness. Their work reveals that ECT is the more important property.

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ECT is dependent on the compressive properties of the components and on the conversion and finishing operations. Thus both containerboard and manufacturing quality are factors in achieving adequate ECT.

Because of the emphasis on compressive strength new compressive test methods for evaluating combined board and containerboard have been and are being developed. Simpler ECT test methods for routine control purposes are being considered. Short span compressive tests such as that developed by the Swedish Forest Products Laboratory (STFI compression tests) are coming into wider use to test linerboard and medium (Cavlin and Fellers, 1975).

Recently, we have shown that the compressive strength of paperboard is related to the elastic stiffnesses because the fibrous elements within the sheet become unstable and buckle (Habeger and Whitsitt, 1983). These stiffnesses can be conveniently measured using nondestructive ultrasonic techniques (Mann, et al., 1980). Because of their nondestructive nature, ultrasonic techniques can be used on the paper machine for measurement and control purposes (Baum and Habeger, 1980).

The purpose of this paper is to briefly review progress in these areas. The results discussed were obtained at the Institute in research sponsored by the Fourdrinier Kraft Board Group of the American Paper Institute. Their support is gratefully acknowledged.

RING CRUSH AND STFI COMPRESSION TESTS

Ring crush is a common way to measure the compressive strength of containerboard. However, the STFI short span compression test is coming into wider use. The STFI compression test is simple, accurate and appears to have many advantages.

Ring crush is a more complex test than the short span type test because of its cylindrical

geometry. There are also differences in mode of failure. In ring crush tests on lightweight materials failure occurs by buckling; on heavy weight materials failure occurs at the loaded edges which are weakened by cutting as the specimens are prepared.

If we keep these factors in mind, ring crush and short span STFI compression test results can then be correlated, particularly over a range of board weights. Figures 1 and 2 illustrate such relationships for lightweight (26- and 33-lb linerboards) and heavyweight (42- and 69-lb linerboards), respectively. The relationship for medium is similar to that for the lightweight linerboards as would be expected. For many purposes such relationships can be useful. However, because of the differences between the tests such relationships will not hold under all paper-making conditions. For example, when medium is wet pressed to varying degrees, figure 3 shows that CD ring crush exhibits a maximum, whereas the STFI compression test results increase steadily over the density range. The ECT results achieved with these mediums increased in the same way as the STFI compressive test results (fig. 4). Thus the short span STFI results were more indicative of the fluted performance of the medium than ring crush. Seth (1984) has also noted that ring crush results on lighter weight sheets pass through a maximum as density increases.

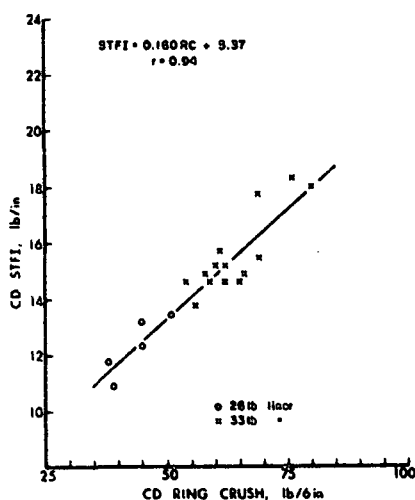


Figure 1.--CD STFI vs. CD ring crush for lightweight liners.

Ring crush and short span STFI compression test results exhibit significantly different MD/CD ratios. This indicates the tests are affected differently by such papermaking factors as fiber orientation and wet strain. These differences are believed to be due to the circular configuration and buckling modes of failure associated with the ring test.

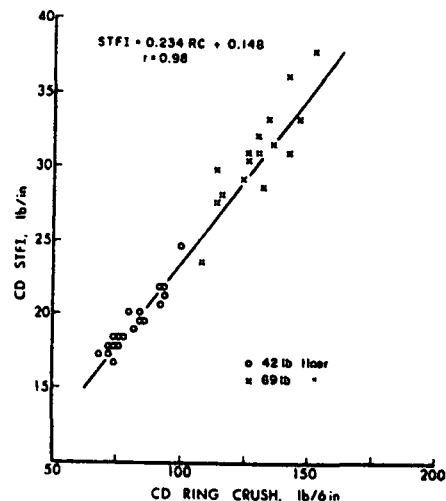


Figure 2.--CD STFI vs. CD ring crush for heavier weight liners.

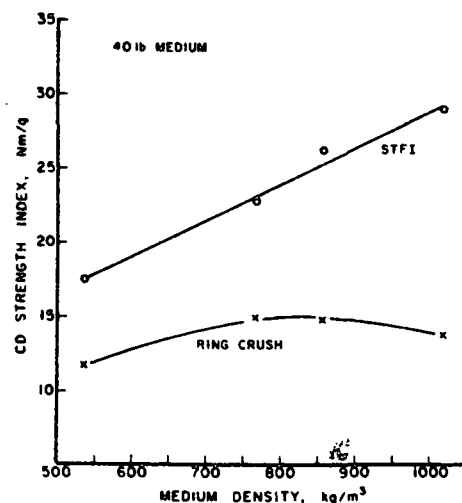


Figure 3.--CD STFI and ring crush show different trends with increasing medium density.

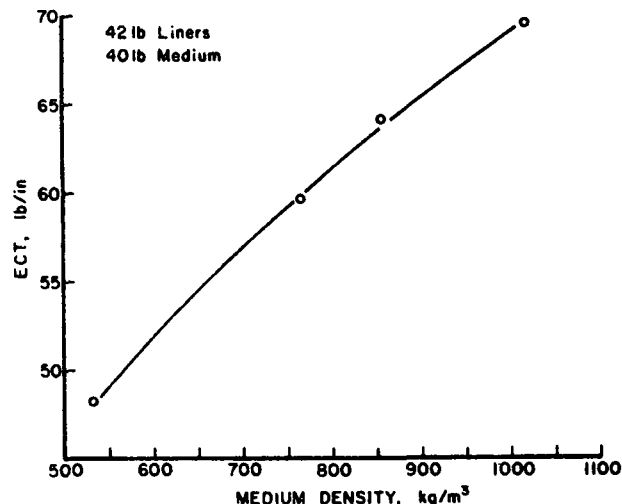


Figure 4.--Wet pressing medium to higher densities increases the ECT of combined board.

For present purposes we have related ECT to short span compressive strength tests on the liner and medium. Figure 6 shows that ECT results are well correlated to the STFI strengths of the components for boards made with a wide range of component basis weights. The overall correlation coefficient is high as would be expected from the basis weight range; however, the within grade correlations were also statistically significant and relatively favorable. In general, it appears that short span STFI compression test results are quite well related to ECT. Similar results have been reported by Seth (1985).

As we mentioned earlier compressive strength is dependent on the elastic stiffnesses of linerboard and medium. Figure 7 shows that ECT is also well related to the elastic stiffnesses of the components. Thus, nondestructive techniques for measuring the elastic properties can be used to characterize the compressive strength and other physical properties of paperboard.

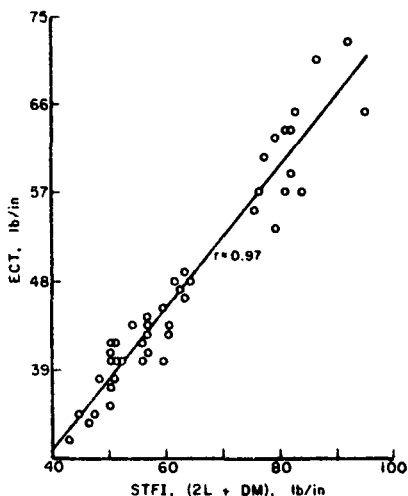


Figure 6.--Relation between STFI and ECT for liner combinations.

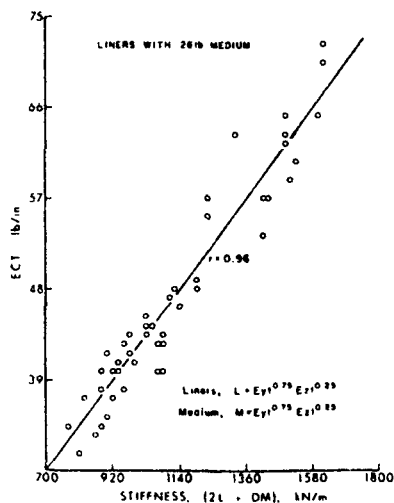


Figure 7.--Relation between ECT and elastic stiffnesses for liner combinations.

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